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FROST SENSITIVITY AND RESPROUTING BEHAVIOR OF ANALOGOUS SHRUBS OF CALIFORNIA AND CHILE

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Detailed comparisons of the structure and function of sclerophyll vegetations centered in the matched climatic regions of central Chile and coastal California have shown a large degree of similarity in spite of divergent evolutionary histories of the floras of these 2 areas (Mooney *et al.*, 1970; Mooney *et al.*, 1977; Parsons, 1976). Principal differences are related to features responsive to land-use treatment which has differed substantially between regions, particularly in the past century (Mooney *et al.*, 1972; Aschmann and Bahre, 1977).

Additional functional differences between these vegetations, particularly in phenological patterns of the woody plants, have been ascribed in part to the small climatic dissimilarities that exist between regions (Mooney *et al.*, 1977). The broad aspects of the climate of the 2 regions are, however, quite similar. Monthly rainfall, drought duration, and mean temperatures can be matched station for station in coastal California and Chile (di Castri, 1973). Furthermore, the direction and magnitude of climatic changes that have occurred from the Pleistocene to the present have been quite comparable (Miller *et al.*, 1977).

The principal climatic difference between regions is that Chile has a more equable thermal environment, evidently because of the more pronounced maritime influence. Frosts are uncommon in coastal Chile but frequent at equal latitude California stations (Miller *et al.,* 1977). This could explain the more prolonged flowering and fruiting period of shrubs in Chile than in California at sites that are otherwise closely matched (Mooney *et al.,* 1977).

If indeed differences in climatic equability between regions have had an important evolutionary impact on the vegetation, this might be evident in their differing frost sensitivities. A spell of unusually cold weather in California led to a test of this possibility.

During December 1972 there was a record freeze in California of a duration that had not occurred for the previous 40 yrs. In the San Francisco Bay region, at Palo Alto, temperatures dipped to − 5 C on 2 separate days (U.S. Weather Bureau, 1972). Widespread damage occurred to exotic plantings in this area.

In 1968 a garden was established at the Carnegie Institution of Washington, at Stanford University, consisting of a large number of species of evergreen trees and shrubs characteristic of the Californian chaparral and of the Chilean matorral. Additionally, a number of subligneous species, generally drought deciduous, from both regions were planted. Plants were grown from seed, mostly collected from the same latitude in California and Chile (33°), thus from comparative generalized mediterranean-type climates (di Castri, 1973). The Carnegie garden is located at a higher latitude (37°N) than the origin of the study populations; however, many species extend naturally to these higher latitudes. At the time of the 1972 freeze these plants had grown to full-sized shrubs.

Considerable damage was noted on many plants subsequent to the freeze. Observations were made on the extent of their recovery the following summer. For most species 10 individuals were observed.

Results

Only 2 of the 9 California evergreen species were damaged by the freeze; both were *Rhus* species (Table 1). Both species are restricted to latitudes lower than the other Californian evergreens. *Rhus laurina,* normally found only at the lowest elevations within the chaparral or within the coastal sage drought-deciduous community, had the greatest mortality. Both species, however, had individuals that base-sprouted. Resprouting from stems of *Rhus ovata* was also noted.

Three Californian drought-deciduous species, *Artemisia californica, Encelia californica,* and *Ptelea aptera,* had individuals that were frost killed, as well as those that recovered by base sprouting. The other 5 Californian drought-deciduous species were undamaged.

Thus, less than one-third of the Californian species were frost damaged. Of these, all had individuals that recovered by base-sprouting.

TABLE 1. CONDITION OF PLANTS SIX MONTHS SUBSEQUENT TO FREEZE.

CALIFORNIA ORIGIN	% No damage	% Dead	% Resprouting
Evergreen species			
Rhus laurina	0	60	40
Rhus ovata	0	20	80
Adenostoma fasciculatum	100	0	0
Cercocarpus betuloides	100	0	0
Heteromeles arbutifolia	100	0	0
Prunus ilicifolia	100	0	0
Quercus agrifolia	100	0	0
Rhamnus ilicifolia	100	0	0
Umbellularia californica	100	0	0
Drought Deciduous species			
Artemisia californica	0	60	40
Encelia californica	0	40	60
Ptelea aptera	0	40	60
Adolphia californica	100	0	0
Fraxinus trifoliata	100	0	0
Salvia apiana	100	0	0
Salvia leucophylla	100	0	0
Salvia mellifera	100	0	0
CHILEAN ORIGIN			
Evergreen species			
Azara celastrina	0	0	100
Baccharis paniculata	0	0	100
Beilschmiedia miersii	0	0	100
Colliguaya odorifera	0	0	100
Cryptocarya alba	0	20	80
Escallonia pulverulenta	0	0	100
Lithraea caustica	0	66	33
Schinus latifolius	0	40	60
Escallonia illinita	100	0	0
Quillaja saponaria	100	0	0
Maytenus boaria	100	0	0
Drought Deciduous species			
Flourensia thurifera	0	60	40
Lepechinia salviae	0	75	25
Lobelia chilensis	0	20	80
Lobelia polyphylla	0	60	40
Podanthus mitiqui	0	0	100
Trevoa trinervis	0	33	66

In contrast, over 80% of the Chilean species were frost damaged, including all the drought-deciduous elements. As with the Californian species, all the damaged species had individuals that recovered by resprouting. There was a somewhat higher mortality of drought-deciduous than of evergreen plants, particularly among the Chilean species.

Discussion and Summary

There was a considerable difference in tolerance of Chilean and Californian species to a substantial freeze. As a group the Chilean species were considerably more sensitive, as was predicted. It can be inferred from these results, which are supported by modern climatic data, that the Chilean species have not been subjected to as cold temperatures as have those from California, in their native habitat. Thus, although the general climatic pattern of summer drought and cool, wet winter is comparable in the 2 regions, the climates differ in a biologically important parameter, i.e., frequency of cold temperatures.

This evidently has resulted in the selection of vegetations that, although similar appearing (Mooney *et al.*, 1970; Parsons, 1976) and similarly adapted physiologically (Mooney and Dunn, 1970), differ in certain significant physiological features.

All Californian and Chilean frost-damaged species recovered by base or "stump" sprouting. Stump sprouting is often cited as an evolutionary response to a fire climate. However, as Axelrod (1973) has noted, most species that are associated with California chaparral today have been in evistence for over 12 to 18 million yrs.—long *before* the origin of a regional summer drought; hence a pronounced fire climate.

It is thus quite likely that resprouting behavior has evolved as a more general adaptive response to such environmental stresses as cold and drought, both of which increased in intensity coincident with evolution of the sclerophyll vegetation (Axelrod, 1973). This survival feature would thus be a "pre-adaptation" to fire, which would be reinforced as the mediterranean climate developed fully.

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TWO NEW LOCAL UMBELLIFERAE (APIACEAE) FROM CALIFORNIA

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Current interest in the possible extirpation of increasing numbers of restricted populations of native plants in California has focussed attention on narrow endemics of all sorts, since they are especially vulnerable. The names of two such examples have been entered on one or more of the lists of rare or endangered species without having been properly legitimized. The purpose of this contribution is to describe and illustrate them, since it seems unwise to delay their debut any longer.

Angelica callii Mathias & Constance, sp. nov. Plantae caulescentes crassae 1–2 m altae, foliis glabris minute scaberulisve, inflorescentia scaberula hirsutulave; folia ovata ternato–1–2–pinnata, divisionibus principalibus interdum reflexis rhacidibus geniculatis, foliolis lanceolatis ovato-lanceolatisve 3–13 cm longis, 1.5–4 cm latis, acutis vel obtusis, acute serratis; petioli 0.5–3 dm longi basi anguste vaginantes; folia cauline sursum reducta plerumque pinnata, foliis summis dilatatis sine lamina; pedunculi paulo graciles 1–2 dm longi; involucrum nullum; involucellum plerumque nullum; radii 25–50 subaequales patenti-adscendentes basi conspicue connati 2.5–7(–10) cm longi; pedicelli plures inaequales patenti-adscendentes basi conspicue connati 5–15 mm longi; flores albi vel subrosei, petalis ovalibus obovatisve basi extra paulo hirsutulis, stylopodio conico quam stylis gracilibus breviore, ovariis hirsutulis; carpophorum bipartitum; fructus ovalis obovatusve 3.5–5 mm longus, 2.5–4 mm latus, hirsutulus glabratusve, costis dorsalibus demissis rotundatis coarctatis suberosis quam intervallis multo latioribus, costis lateralibus quam eis dorsalibus multo latioribus suberosis, quam corpore fructus plerumque angustioribus; vittae ad valleculas solitariae magnae ad pericarpium adherentes; chromosomatum numerus $n = 11$. Fig. 1.